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[54] **VACUUM PUMP WITH MAGNETIC BEARING SYSTEM AND BACK-UP BEARINGS**

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[52] **U.S. Cl.** **415/90**; 415/90; 415/111; 415/229; 415/230; 415/170.1; 384/101; 384/102; 310/90.5

[58] **Field of Search** 415/90, 111, 229, 415/230, 170.1; 384/101, 102; 310/90.5

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,023,920	5/1977	Bächler et al. .	
4,312,628	1/1982	Yamamura	417/424
5,165,872	11/1992	Fleischmann et al.	417/423.4
5,238,362	8/1993	Casaro et al. .	
5,747,907	5/1998	Miller	310/90

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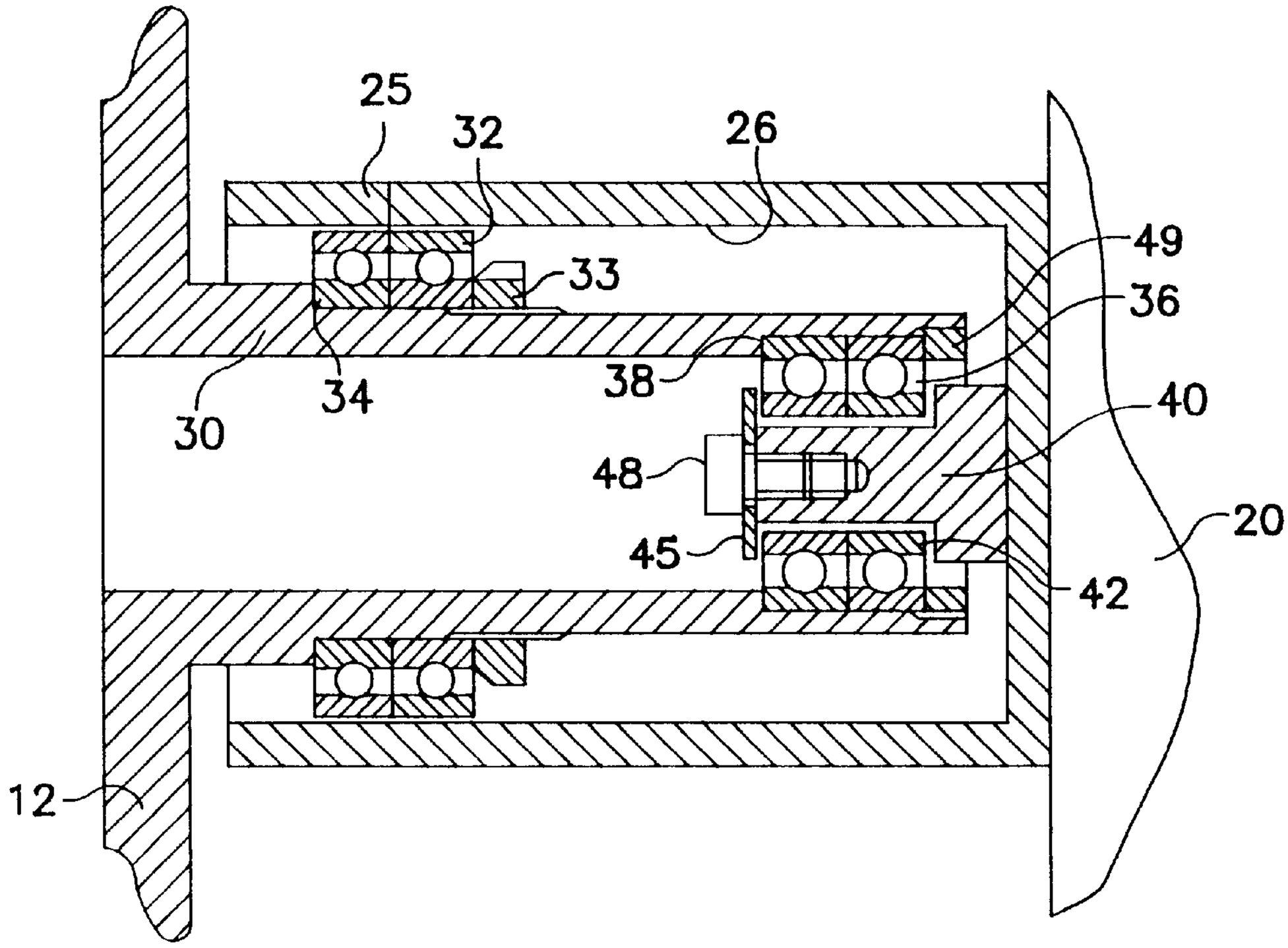
[57] **ABSTRACT**

A vacuum pump is provided with back-up bearings in addition to magnetic bearings for supporting its rotor with respect to the pump housing. The rotor has a hollow rotary shaft extending backwards enclosing in its inner space a forwardly protruding tubular shaft affixed to the pump housing, and another cylindrical member affixed to the rotor protrudes backward inside this fixed tubular shaft. One set of back-up bearings is provided on the outer surface of the fixed tubular shaft spaced from the inner surface of the rotor shaft and another set of back-up bearings is provided on the inner surface of the fixed tubular shaft, spaced from the protruding cylindrical member. The back-up bearings thus positioned can be made smaller for improved dynamic emergency capabilities.

9 Claims, 2 Drawing Sheets



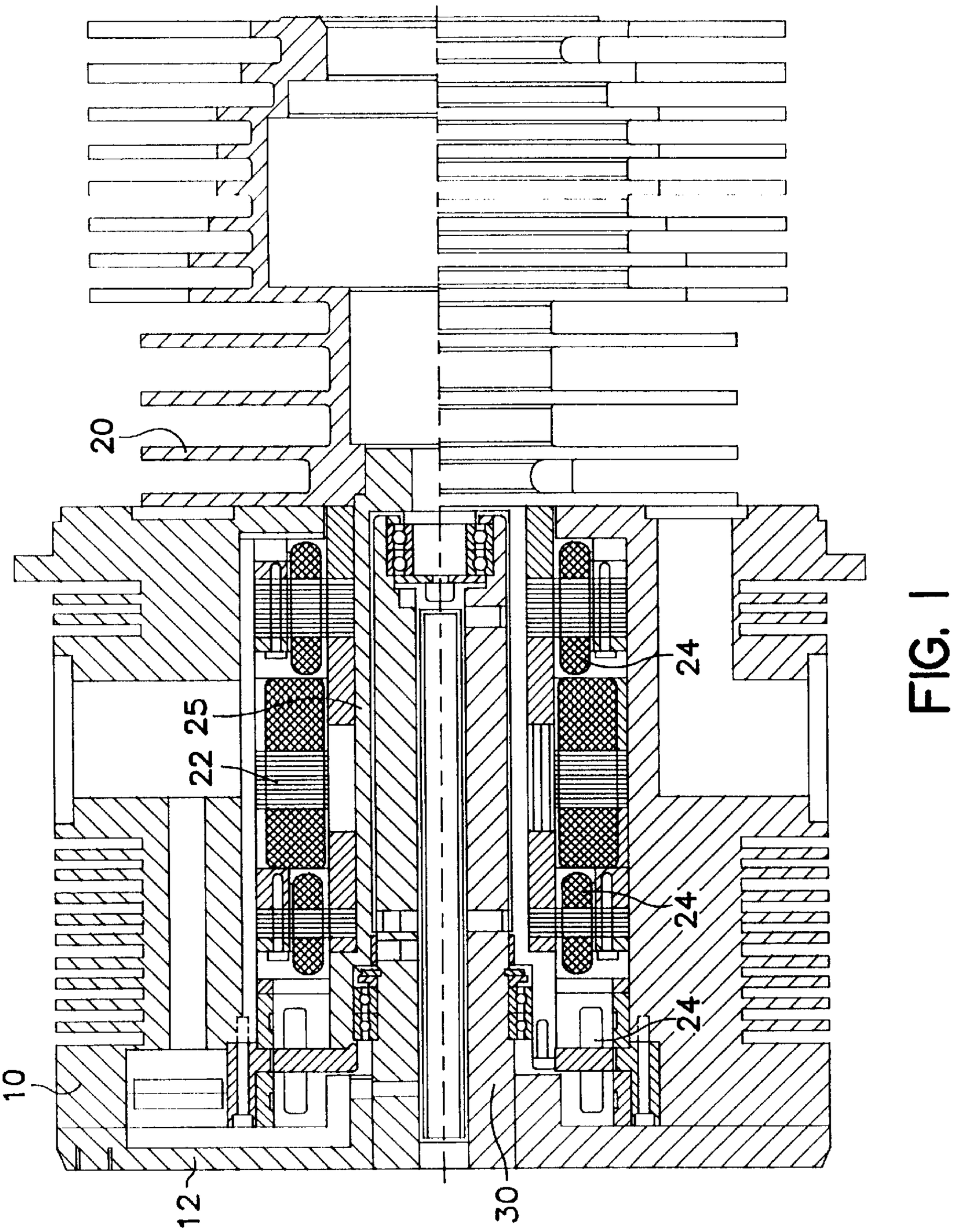


FIG. 1

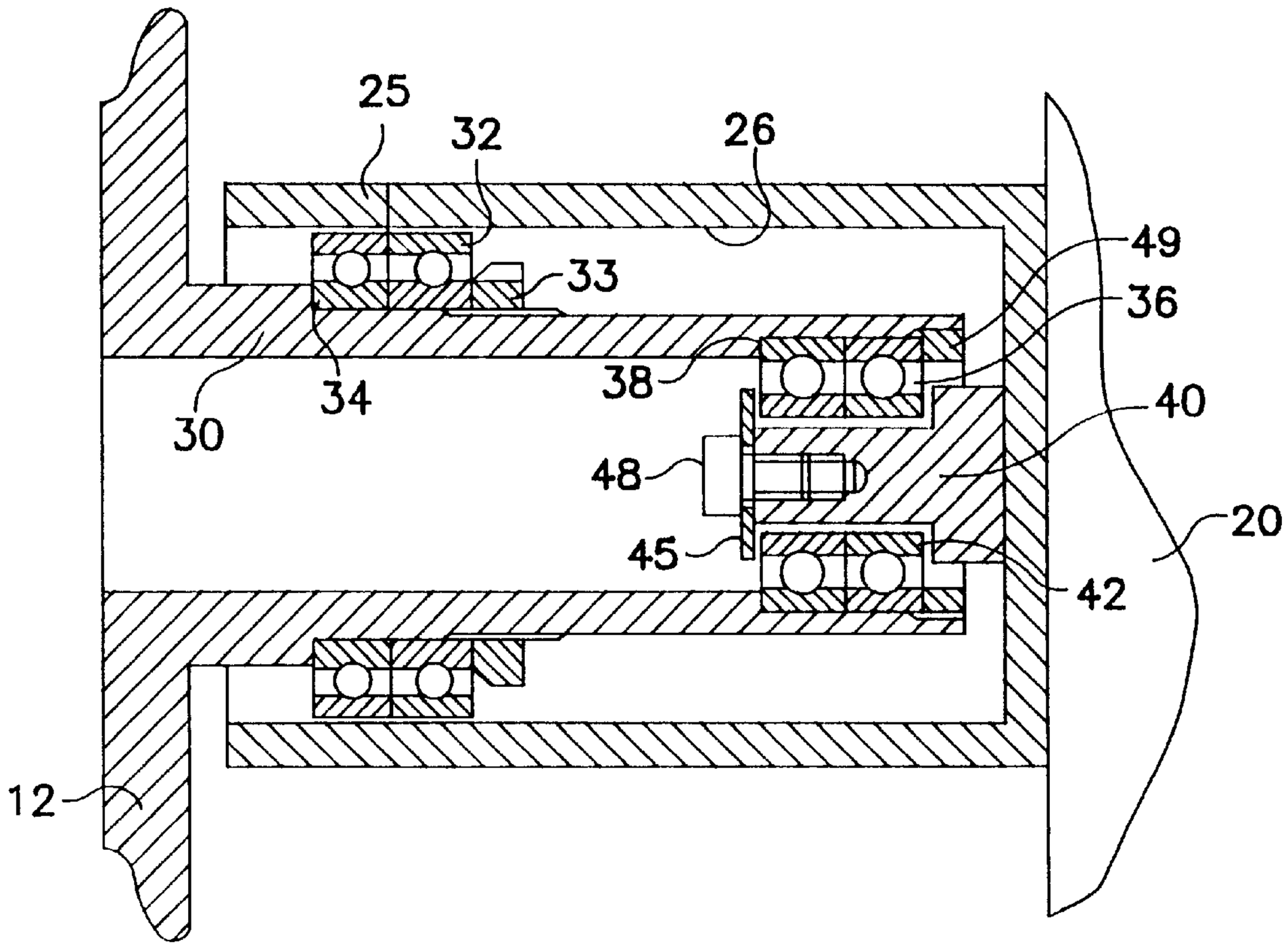


FIG. 2

VACUUM PUMP WITH MAGNETIC BEARING SYSTEM AND BACK-UP BEARINGS

BACKGROUND OF THE INVENTION

This invention relates to a vacuum pump with a bearing assembly and more particularly to the vacuum pump with a magnetic bearing system of the kind having back-up bearings contained inside the shaft of the vacuum pump. This mechanical bearings set up is disclosed in the U.S. patent application No. 08/858,230 filed by Varian Associates, Inc.

The U.S. Pat. No. 5,238,362 issued Aug. 24, 1993 to Casaro, et al. discloses a turbomolecular vacuum pump for which a system according to this invention can be suitable and is assigned to the assignee herein. This patent will be incorporated herein by reference, detailed accounts of some of common components of a vacuum pump being thus omitted.

Although a vacuum pump according to aforementioned U.S. Pat. No. 5,238,362 provides increased compression ratios, it is desirable to keep improving the quality of such a vacuum pump, for example, by providing an improved bearing assembly with improved capability in radial and axial position sensing and a reduced size.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a vacuum pump with an improved magnetic bearing system having back-up bearings and more particularly to the turbopump with such a system which is compact and easy to disassemble.

A magnetic bearing system of the vacuum pump embodying this invention, with which the above and other objects can be accomplished, may be characterized not only as comprising a rotor with a hollow rotary shaft, a pump housing enclosing the rotor and magnetic bearings for supporting the rotor inside the pump housing, but also wherein a fixed tubular shaft is disposed inside the rotary shaft, supporting a set of back-up bearings on its outer surface spaced from the inner wall of the rotor shaft and another set of back-up bearings on its inner surface. A cylindrical member attached to the rotor protrudes into the inner space of the tubular fixed shaft, spaced by a small gap from the internally mounted back-up bearings.

The mechanical back-up bearings, thus mounted, can be made smaller than back-up bearings used in prior art magnetic bearing systems, thereby improving the dynamic emergency capabilities of the magnetic bearing system.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIG. **1** is a sectional view of a magnetic bearing system embodying this invention incorporated in a vacuum pump; and

FIG. **2** is a schematic sectional view of a portion of the system shown in FIG. **1**.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a magnetic bearing system embodying this invention incorporated in a vacuum pump of the kind disclosed in aforementioned U.S. Pat. No. 5,238,362,

numeral **10** indicating the housing structure of the vacuum pump and numeral **20** generally indicating its rotor, enclosed inside the pump housing **10**. Numeral **22** indicates an electric motor for the rotation of the rotor **20** and numeral **24** indicates magnetic bearings which may be of a known kind, disclosed, for example, in U.S. Pat. No. 4,023,920 for magnetically supporting the rotor **20** with respect to the pump housing **10**.

FIG. **2** shows schematically a portion of FIG. **1** where mechanical back-up bearings are provided for continuing to support the rotor **20** with respect to the pump housing **10** in the case of an emergency where the magnetic bearings **24** fail to function properly. With reference simultaneously to FIGS. **1** and **2**, and more particularly to FIG. **2**, numeral **25** indicates a longitudinally elongated rotary shaft (or "the rotor shaft") which is attached firmly to the rotor **20**, extending longitudinally backward (to the left with reference to FIGS. **1** and **2**) and around the axis of which the rotor **20** is adapted to rotate. As shown in FIGS. **1** and **2**, the back end part of the rotor shaft **25** is tubular, having a cylindrical inner wall **26** which encloses therein a longitudinally elongated inner space opening to the back.

The pump housing **10** has a flange part **12** attached thereto at its back end. A stationary tubular cylindrical shaft (hereinafter referred to as "the fixed shaft **30**") for supporting the aforementioned back-up bearings (to be described in detail below) is attached to this flange **12**, protruding in the forward direction therefrom coaxially with and in the inner space of the rotor shaft **25**. The rotor **20** has a cylindrical protrusion **40** which is coaxial with the rotor shaft **25** and extends backwards, penetrating into the hollow interior of this fixed shaft **30** from the front side.

A set of mechanical annular bearings **32** (hereinafter referred to as "the backward backup bearings") is mounted on the outer surface of the fixed shaft **30** at a relatively backward position, with their external surfaces spaced from the inner wall **26** of the rotor shaft **25**, leaving a specified gap therebetween. An annular nut **33** with a threaded inner surface is similarly mounted in front of the backward back-up bearings **32**, engaging with a threaded portion on the outer surface of the fixed shaft **30** such that the backward back-up bearings **32** can be pushed backward, as the nut **33** is rotated, against a step **34** formed on the outer surface of the fixed shaft **30**, as shown in FIG. **2**, such that the backward back-up bearings **32** can be securely fastened to the fixed shaft **30**, prevented from sliding in the longitudinal direction during the operation of the vacuum pump.

Another set of mechanical annular bearings **36** (hereinafter referred to as "the forward back-up bearings") is mounted on the inner wall of the fixed shaft **30** near its forward end such that their inner surfaces are in a face-to-face relationship with but spaced from the outer cylindrical surface of the protrusion **40**, leaving a specified gap therebetween. The forward backup bearings **36** are sandwiched between a step **38** formed on the inner surface of the tubular fixed shaft **30** and the side surface of nut **49** when screwed on the suitable thread in the inner surface of shaft **30**, as shown in FIG. **2**, so as to be prevented from changing their positions in the longitudinal direction during the operation of the vacuum pump.

An axial stopper plate **45** is attached to the tip (or the backward end) of the backwardly extending protrusion **40** by means of a screw **48**, serving to prevent the protrusion **40** from sliding forward with respect to the fixed shaft **30**. The step **42** formed on the cylindrical protrusion **40** serves to prevent the protrusion **40**, and so the rotor shaft **25** and the

rotor **20**, from sliding backward with respect to the fixed shaft **30**. A predetermined axial gap is left between forward backup bearing set and both stopper means: the axial stopper plate **45** and step **42**.

Although the invention has been described above by way of a single embodiment, this embodiment is not intended to limit the scope of the invention. Many modifications and variations are possible within the scope of the invention. Although the vacuum pump, into which the present invention is intended to be incorporated, has been only schematically described, neither is this schematic description intended to limit the scope of the invention. In general, it is expected that magnetic bearings be provided for the displacement of the rotor shaft both in the radial and axial directions, and sensors for such displacements are usually provided. Positioning of such magnetic bearings and sensors is not intended to limit the scope of the invention.

One of the advantages of the present invention, as described above, is that the back-up bearings, being disposed inside the rotor shaft **25** can be made smaller, independent of the size of the magnetic bearings. In particular, the forward back-up bearings **36**, attached inside the fixed shaft **30** which is disposed inside the rotor shaft **25**, can be made conveniently smaller. Being smaller and having smaller masses of rolling elements, the forward back-up bearings **36**, in particular, have the capability of faster acceleration, providing better dynamic emergency capabilities.

The components according to this invention are also easier to assemble to produce the whole system. Because of the open tubular design of the rotor shaft **25**, the system can be disassembled easily from the back side, and the back-up bearings can be changed even if the system is accessible only from the back side (which is the lower side if the pump is set up in the vertical orientation).

All such modifications and variations that may be apparent to a person skilled in the art are intended to be included within the scope of this invention.

What is claimed is:

1. A vacuum pump with a magnetic bearing system including a rotor, a pump housing enclosing said rotor and magnetic bearings for supporting said rotor with respect to said pump housing, said magnetic bearing system comprising:

a rotary rotor shaft attached to said rotor so as to rotate with said rotor, said rotor shaft having an axially elongated tubular back end part having a cylindrical inner wall which encloses an inner space therein;

a fixed tubular shaft being affixed to said pump housing and extending forward inside said inner space coaxially with said rotor shaft;

backward back-up bearings set supported externally around said fixed tubular shaft inside said inner space of said rotor shaft and spaced from said inner wall of said rotor shaft;

a cylindrical protrusion affixed to said rotor so as to rotate coaxially with said rotor shaft and extending backward inside said fixed tubular shaft; and

forward back-up bearings set contained inside and attached coaxially to said fixed tubular shaft so as to be opposite to and spaced from said protrusion.

2. The vacuum pump with the magnetic bearing system of claim **1**, further comprising a protrusion stopper means for maintaining said protrusion and said forward back-up bearings in a mutually opposite positional relationship.

3. The vacuum pump with the magnetic bearing system of claim **2**, wherein said protrusion stopper means includes a plate and a screw for fastening said plate to a front end of said protrusion, wherein said rotor becomes removable from said pump housing by removing said screw from said protrusion, said plate and said set of forward back-up bearings form a gap therebetween.

4. The vacuum pump with the magnetic bearing system of claim **3**, wherein said protrusion stopper means further comprising a step which is formed therein, said step and said set of forward back-up bearings form a gap therebetween.

5. The vacuum pump with the magnetic bearing system of claim **1**, wherein said forward back-up bearings are axially at a forward position with respect to said backward back-up bearings.

6. The vacuum pump with the magnetic bearing system of claim **1**, further comprising backward back-up bearing affixing means for preventing said backward back-up bearings from sliding axially along said fixed tubular shaft.

7. The vacuum pump with the magnetic bearing system of claim **6**, wherein said backward back-up bearing affixing means include a step which is formed on an external surface of said fixed tubular shaft and a ring nut mounted on said external surface of said fixed tubular shaft serving to press said backward back-up bearing axially backward against said step.

8. The vacuum pump with the magnetic bearing system of claim **1**, further comprising forward back-up bearing affixing means for preventing said forward back-up bearings from sliding axially along said fixed tubular shaft.

9. The vacuum pump with the magnetic bearing system of claim **8**, wherein said forward back-up bearing affixing means comprise a step which is formed on an interior surface of said fixed tubular shaft and a ring nut mounted on said interior surface of said fixed tubular shaft serving to press said forward back-up bearing axially backward against said step.

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